

# 独叶草属的胚胎学及其系统学意义\*

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## KINGDONIA, EMBRYOLOGY AND ITS SYSTEMATIC SIGNIFICANCE

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**Abstract** The embryological studies show that *Kingdonia* is similar to *Circaeaster* while different from other members of the Ranunculales (sensu Takhtajan, 1980) in development of endosperm and embryo. We consider that there is close systematic relationship between *Kingdonia* and *Circaeaster*.

**Key words** *Kingdonia*; Embryology; Systematic relationship

*Kingdonia*, with only one species, *K. uniflora* Balf. f. et W. W. Smith, is special in many characteristics, for instance, the dichotomous leaf venation, like that of *Circaeaster*. The embryological characteristics of *Circaeaster* are unique (Hu & Yang, 1987; Junell, 1931), while the embryology of *Kingdonia* remains unknown except ovule, gametophyte, fertilization, and early endosperm development (Mu, 1984, 1983).

### 1 Materials and Methods

The materials, collected from the Taibai Mountains, Shaanxi Province from May to August, 1994 and 1995, were fixed in FAA, dehydrated in the alcohol series, infiltrated with xylene and embedded in paraffin wax. The embedded materials were sectioned at 6~8  $\mu$ m thick, stained with safranin and counter-stained with fast green, or stained with iron-alum haematoxylin and counter-stained with orange G. The contents of endosperm cells were stained by PAS reaction, Sudan black B, and Coomassie brilliant blue.

### 2 Observations

The structure of ovules and development of embryo sacs have been already reported (Hu & Tian, 1985; Mu, 1984). In this paper we focus on the development of embryos and endosperm, and the changes of integuments, nucellus, sterile megasporangia and antipodal cells during that developmental stage were also briefly described.

After fertilization, the primary endosperm nucleus divided longitudinally into 2 longitudinally elongated cells (Plate I : 2), which soon divided transversely into 4 cells, and the zygote divided at this time (Plate I : 3~5). These endosperm cells divided both transversely and longitudinally into multi-celled endosperm (Plate I : 6) and then began to differentiate in the following process. The cells near the chalaza became larger, irregular (Plate I :

\* The project was supported by The National Natural Science Foundation of China (No. 39630030) and the Laboratory of Systematic & Evolutionary Botany, Institute of Botany, the Chinese Academy of Sciences.

1997-09-22 收稿, 1997-11-21 收修改稿。

8), with no starch grains stored in them during the whole developmental process (Plate I : 11), and finally moved to the side near the hilum because of different dividing rates of endosperm cells in different position (Plate I : 10). This part of the endosperm appeared fan-shaped in a longitudinal section (Plate I : 10) and crescent in a cross section (Plate I : 13). Other endosperm cells did not change in shape (Plate I : 8) and contained starch grains (Plate I : 11) and occupied the main part of endosperm (Plate I : 11). At the late torpedo-like embryo stage, the endosperm consisted of densely arranged parachymous cells, and the cells of endosperm surface were regular and subsquare in shape with thicker outer walls (Plate I : 12).

The embryogeny of *Kingdonia* followed the Caryophyllad type of Johansen (1950) (Plate II : 1~5) with slight differences between the two: in *Kingdonia*, the second or the third proembryo cell under the terminal cell divided longitudinally first (Plate II : 6, 7), and then other cells, except the terminal and the basal cell, divided in the same way (Plate II : 8). The proembryo finally developed into a typical globular embryo (Plate II : 13) via the stick-like (Plate II : 9) and the small-globular embryo stages (Plate II : 10~12). More than 99% of fruits fall off at the stage of globular embryo, while in the persistent fruits, seed continually developed till the embryo was at its late torpedo-like stage (Plate II : 14). The torpedo-like embryo was with a vase-like body and a slender, longer stalk (Plate II : 14).

The integument, sterile megasporae, nucellus and antipodal cells underwent some special changes during the embryogeny of *Kingdonia*. Before fertilization, the integument covered 1/3 part of the nucellus (Plate I : 1), while after fertilization, it elongated to cover the nucellus (Plate I : 2, 5). Simultaneously, inner epidermal cells of integument near the micropyle elongated radically to form a palisade-like structure (Plate I : 2, 4, 5) which was out of shape (Plate I : 6) at the 2~3-celled proembryo stage. In the following process, the integument became out of shape (Plate I : 9) and degenerated and then disappeared completely (Plate I : 10~13). This made the seed without testa (Plate I : 10, 13). Most of nucellar cells disappeared after fertilization, but the cells surrounding the sterile megasporae (s), which did not disappear (Plate I : 1, 5), were persistent (Plate I : 2, 5). These nucellar cells formed an obturator-like structure with the sterile megasporae(s) in the micropyle (Plate I : 2, 5). This structure degenerated at 2~3-celled proembryo stage (Plate I : 6). The antipodal cells were persistent and enlarged, and their cytoplasm became dense (Plate I : 2, 5, 6, 8) after fertilization and did not disappear till the stick-like embryo stage.

### 3 Discussion

**3.1** The embryogeny of *Kingdonia* is similar to that of *Circaeaster* (Hu & Yang, 1985). In these two genera, the first longitudinal cell division of proembryo occurs in the second or the third cell under the terminal cell, differing from any variation of the Caryophyllad type, and thus we named this variation a *Kingdonia* variation.

The 2-celled endosperm of *Kingdonia* undergoes cell division immediately after the first division of the primary endosperm nucleus, and therefore the endosperm of *Kingdonia* is cellular. This differs from the observation of Mu (1984).

**3.2** The similarities in embryology among *Kingdonia*, *Circaeaster* and the other members of the Ranunculales are shown in Table 1.

Table 1 The embryological similarities between *Kingdonia*, *Circaeaster* and other members of Ranunculales

| Characteristics                       |                                    | <i>Kingdonia</i>  | <i>Circaeaster</i>   | other Ranunculales   |
|---------------------------------------|------------------------------------|---|--|--|
| embryo                                | development type                   | subtype <i>Kingdonia</i> under Caryophyllad type  | subtype <i>Kingdonia</i> under Caryophyllad type   | <i>Onagrad</i> <sup>3), 6)</sup> , seldom <i>Solanad</i> <sup>7)</sup> type or both <sup>1)</sup>                  |
|                                       | embryo stage when fruits fallen    | late torpedo-like stage   | completely differentiated <sup>5)</sup>  | globular stage or completely differentiated <sup>1), 4), 6), 12)</sup>   |
| endosperm                             | development                        | cellular, first division of primary endosperm nucleus longitudinal  | cellular, first division of primary endosperm nucleus longitudinal <sup>5), 8)</sup>   | only cellular in <i>Lardizabalaceae</i> with primary endosperm nucleus dividing transversal <sup>2), 3), 11)</sup> |
|                                       | differentiation of endosperm cells | differentiating into 2 parts and the part without starch grains at one side of seed                                 | differentiating into 2 parts and the part without starch grains at one end of seed <sup>5), 8)</sup>                             | undifferentiated   |
|                                       | cell wall                          | thin  | thick <sup>5), 8)</sup>  | thin   |
|                                       | outer wall of epidermal cells      | thickened   | thickened <sup>5)</sup>  | not thickened  |
| integument change                     |                                    | covers 1/3 part of nucellus before fertilization; after that, elongating and then disappearing; seeds without testa | covers 1/3 of nucellus before fertilization; after that, elongating and then disappearing; seeds without testa <sup>5), 8)</sup> | covers the whole nucellus before fertilization and developing into testa after fertilization                       |
| palisade-like structure               |                                    | occurring in inner epiderm  | no <sup>5), 8)</sup>   | occurring in both inner and outer integuments in <i>Nandina</i> of Berberidaceae <sup>10)</sup>                    |
| sterile megaspore                     |                                    | 1~2 persistent  | none persistent <sup>5)</sup>  | not reported   |
| obturator-like structure in micropyle |                                    | formed by sterile megaspor(e)s & persistent nucellar  | no <sup>5)</sup>   | not reported   |
| antipodal cells                       |                                    | persistent  | persistent <sup>5)</sup>   | persistent <sup>1), 3), 9)</sup>   |

1) Bhandari, 1968; 2) Bhatnagar, 1965; 3) Davis, 1966; 4) Engell, 1995; 5) Hu & Yang, 1987; 6) Jalans, 1963; 7) Johansen, 1950; 8) Junell, 1931; 9) Sastri, 1969; 10) Schnarf, 1931; 11) Swamy, 1954; 12) Tamura, 1965

**3.3** Based on the synthetic analysis of embryological characteristics, we consider that *Kingdonia* is more closely related to *Circaeaster* than to the other members of the Ranunculales. This consideration agrees with the results of the studies on pollen grains (Nowicke & Skvarla, 1982), chromosomes (Kong & Yang, 1997), leaf venation (Ren *et al.*, 1997; Ren & Hu, 1996) and nuclear ribosomal DNA (Oxelman & Liden, 1995).

**Acknowledgement** The authors are grateful to Prof. Maureen Corr for her revision of the English writing.

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### Explanation of plates

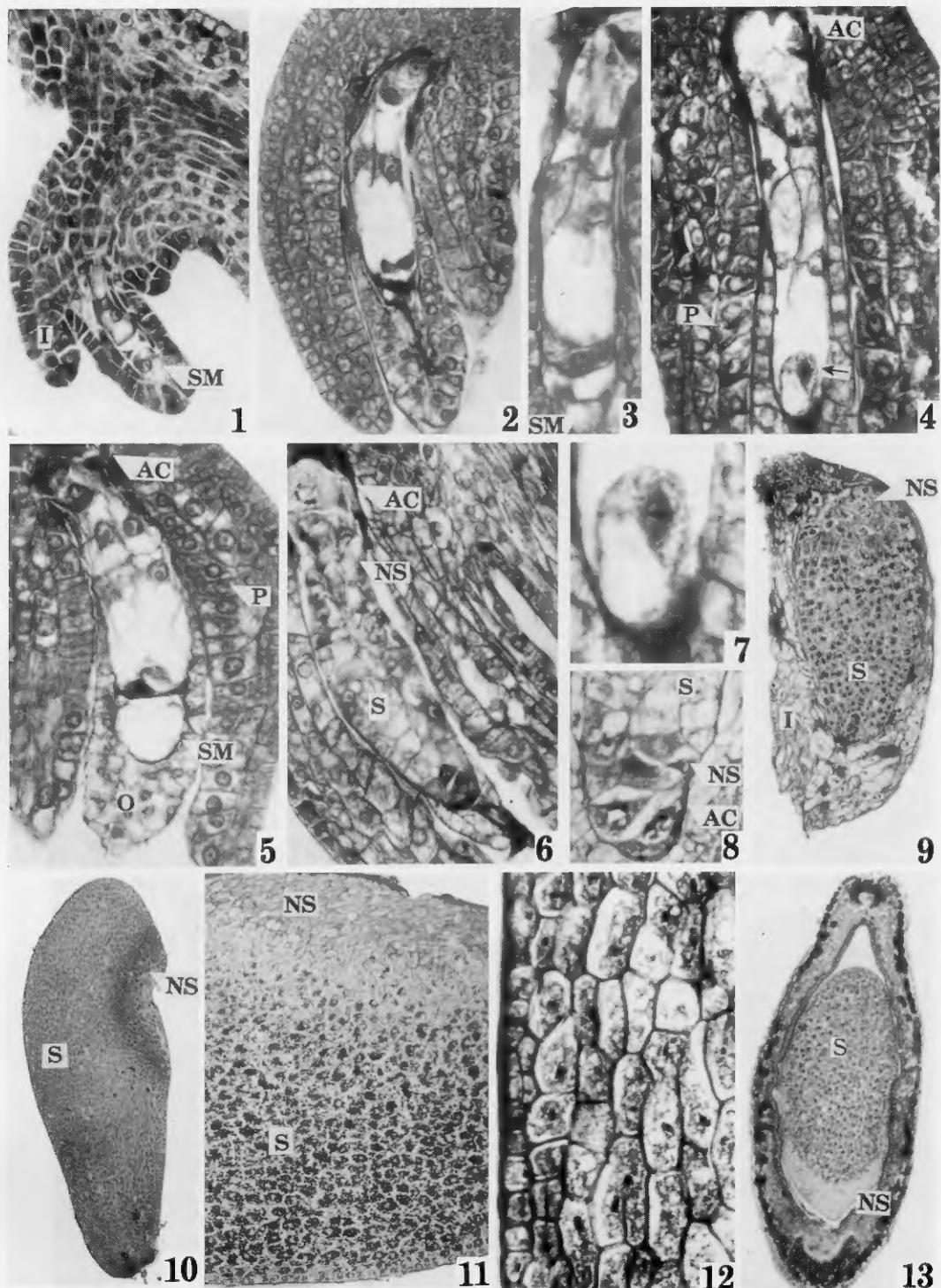
**Plate I** Embryology of *Kingdonia* 1. Longitudinal section of enlarged part of an ovary, showing integument(I) and a persistent sterile megasporangium(SM)( $\times 250$ ). 2. Longitudinal section of 2-celled endosperm( $\times 400$ ). 3~5. 4-celled endosperm: 3. Showing the persistent sterile megasporangium(SM)( $\times 400$ ); 4. Showing the first division of zygote(arrow), persistent antipodal cells(AC) and palisade-like structure of integument(P)( $\times 400$ ); 5. Showing persistent antipodal cells(AC), obturator-like structure(O), Palisade-like structure(P) of integument and persistent sterile megasporangium(SM)( $\times 450$ ). 6. Multi-celled endosperm at 3-celled proembryo

stage and persistent antipodal cell(AC)( $\times 250$ ). 7. Enlarged part shown in Fig. 4, showing the first division of zygote( $\times 500$ ). 8. Enlarged part of endosperm near chalaza, showing differentiation of endosperm(NS: the part without starch grains in cells, S: the part with starch grains in cells, the same below)( $\times 300$ ). 9. Longitudinal section of a young seed in 2-series-celled proembryo stage, showing differentiated endosperm and degenerating integument(I)( $\times 35$ ). 10. Same as Fig. 9, but at stick-like proembryo stage, showing differentiation of endosperm and seed without testa( $\times 30$ ). 11. Enlarged part of endosperm stained by PAS reaction at torpedo-like embryo stage, showing the part without starch grains in cells(NS) in one side of seed( $\times 200$ ). 12. Enlarged part of endosperm at torpedo-like embryo stage, showing the thicker outer wall of epidermal cells( $\times 400$ ). 13. Transversal section of a fruit, showing the seed without testa, and the position and shape of different part of endosperm( $\times 30$ ).

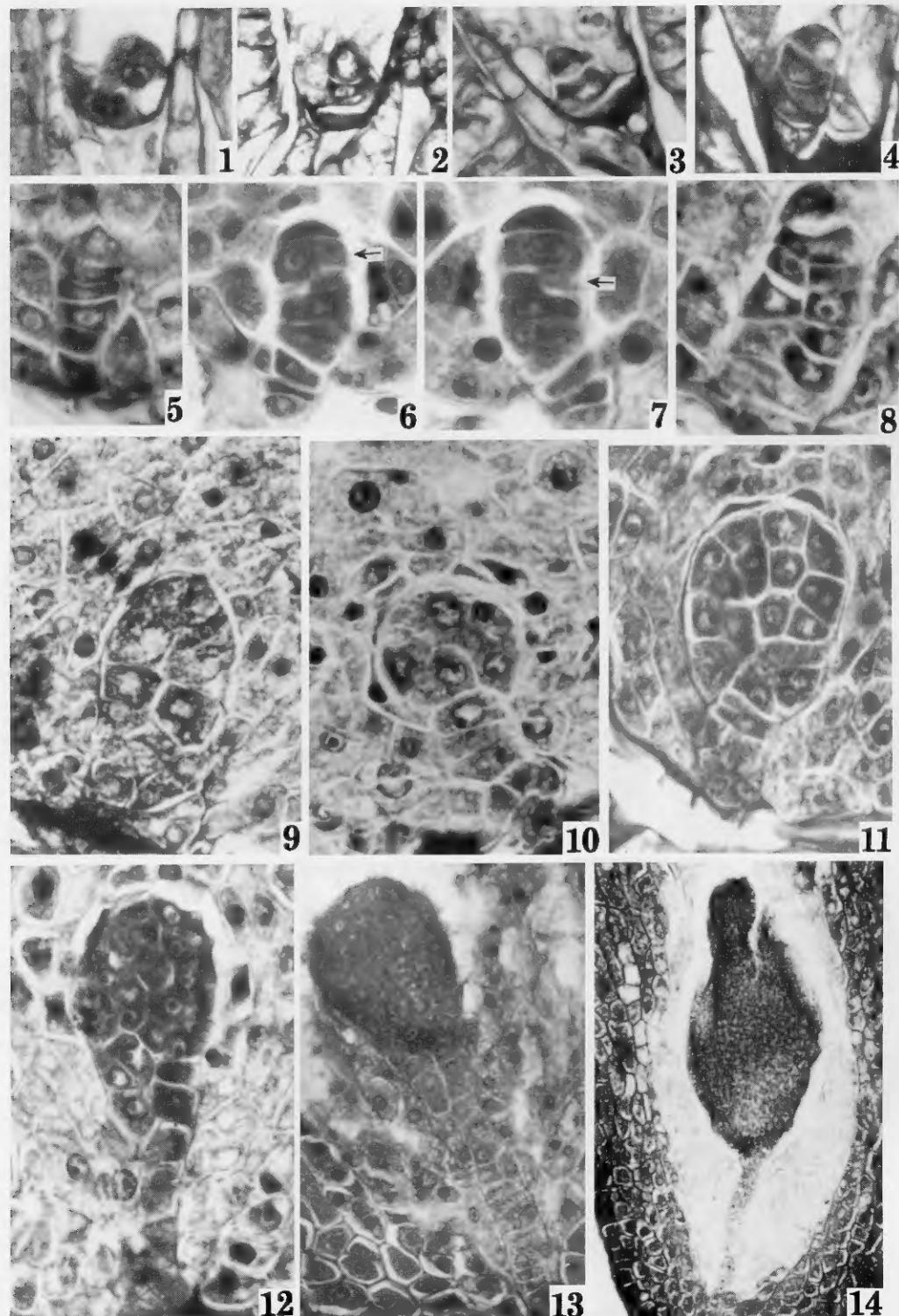
**Plate II** Embryology of *Kingdonia*: Proembryo 1. 2-celled stage( $\times 400$ ). 2. 3-celled stage( $\times 400$ ). 3. 4-celled stage( $\times 350$ ). 4. 5-celled stage( $\times 400$ ). 5. 6-celled stage( $\times 300$ ). 6. 9-celled stage, showing the second or third cell under terminal cell divides longitudinally(arrow)( $\times 300$ ). 7. Same as Fig. 19.  $\times 320$ . 8. Club-shaped embryo, showing the proembryo cells dividing longitudinally except the terminal and basal cell( $\times 300$ ). 9. Club-shaped embryo( $\times 300$ ). 10~14. Small globular embryo of different development degree(10.  $\times 280$ ; 11.  $\times 300$ ; 12.  $\times 280$ ); 13. Globular embryo( $\times 350$ ); 14. torpedo-like embryo( $\times 280$ ).

**摘要** 独叶草属的胚乳发育为五福花型,其早期分化属细胞型;胚胎发育为石竹型下的独叶草亚型;珠被内层的部分细胞形成栅栏组织状,最后消失或近于消失;反足细胞宿存,部分不育大孢子宿存并和部分珠心组织一起形成珠孔塞状结构。这些性状表明它与星叶草属间的相似性要大于与毛茛目其它成员间的相似性。

**关键词** 独叶草属; 胚胎学; 亲缘关系



See explanation at the end of text



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